



Cisco research indicates that the total volume of worldwide IP traffic is doubling every two years.

By 2011, the world's IP networks will transport 29 exabytes of traffic . equivalent to 144 times the total amount of printed matter that exists today. ò ò .. each month!

WELCOME TO THE ZETA BYTE ERA!





The ZetaByte Era and The (R)evolution of the Transport Network



Vernon Thaver (vethaver@cisco.com)

Public Sector: Digital Cities, NReN

SP NGN (Core/Edge, Access/Aggregation and Optical)



Routing and Switching #15661

Agenda

- Evolution of transport networks
- Explosion in internet traffic
- Basics of a DWDM system
- Revolution of transport networks with IPoDWDM (An introduction)
- IPoDWDM benefits and Case studies
- Future Developments





DWDM Technology Basics Review



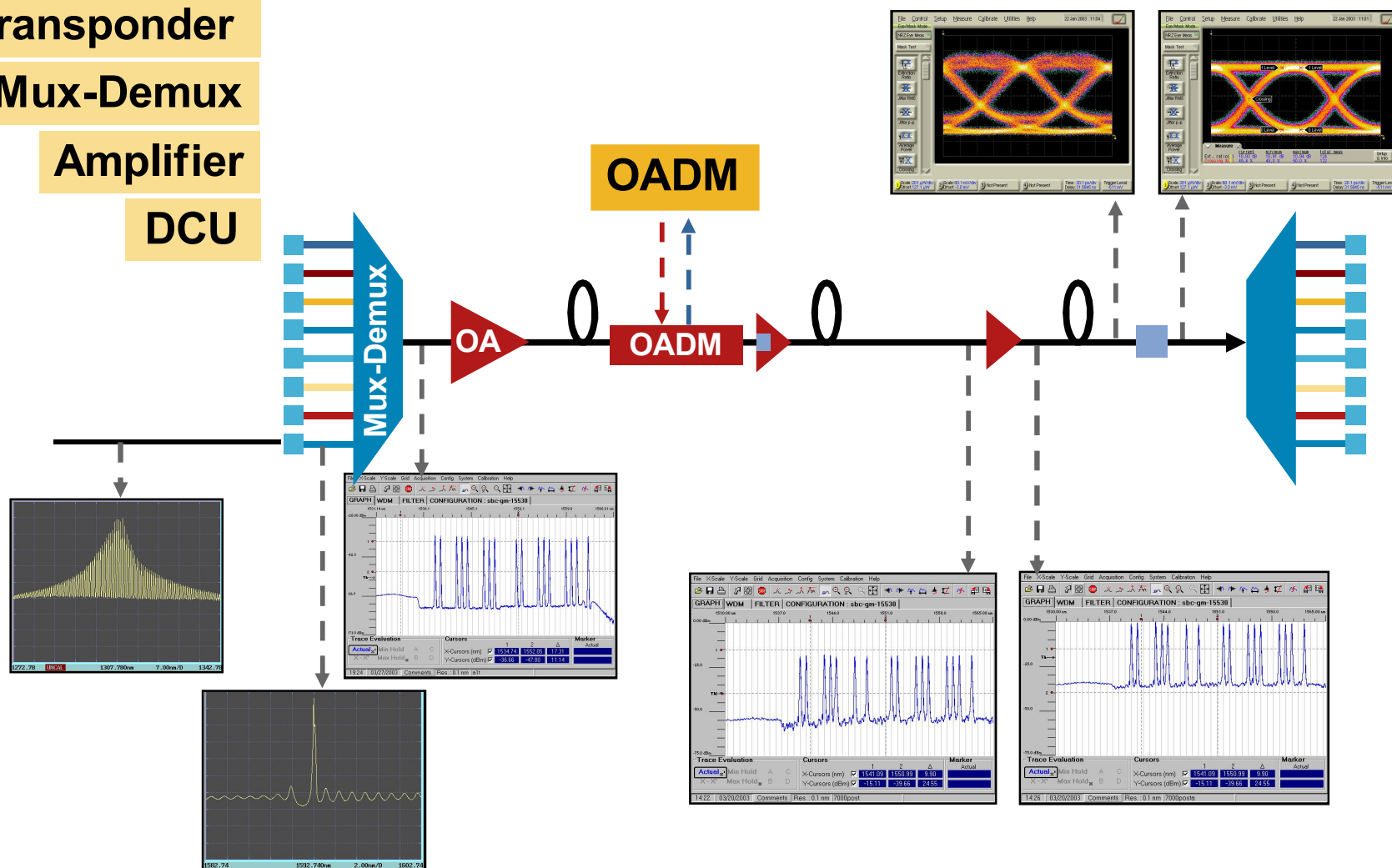
DWDM Systems

Transponder

Mux-Demux

Amplifier

DCU



Optical Impairments

- Attenuation

 - Loss of signal strength

 - Limits transmission distance

 - Optical amp compensates

- Optical Signal to Noise Ratio (OSNR)

 - Noise introduced by optical amplifiers

 - Function of data rate- rule of thumb,
2X data rate = 3 dB higher OSNR

 - Limits number of amps hence distance

 - Forward error correction and
regen counter impact

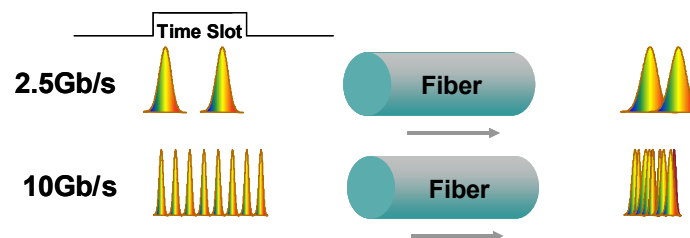
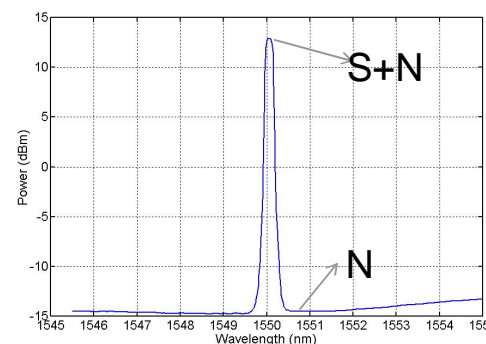
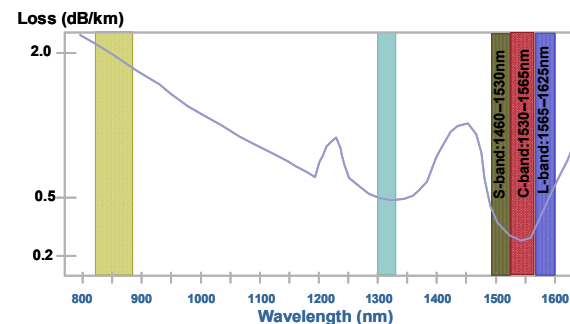
- Chromatic Dispersion (CD)

 - Amps allow greater distance leads
to Distortion of pulses

 - Limits transmission distance

 - Inverse to the square of the data rates

 - Tunable dispersion compensator (TDC)
compensates for effects



Optical Impairments

- Polarization Mode Dispersion (PMD)

Caused by non-linearity of fiber geometry

Very disruptive at higher bit rates ($> 10\text{G}$)

PDMC or regen compensate

- Four Wave Mixing (FWM)

Effects in multichannel systems

Effects for higher bit rates

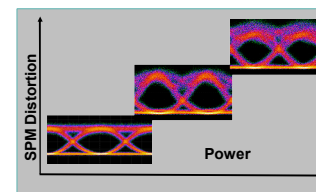
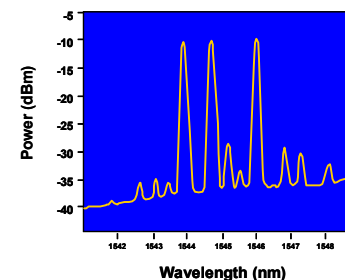
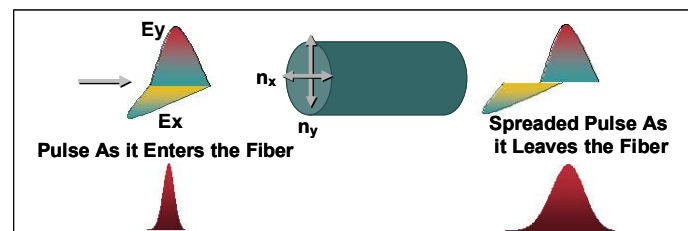
CD, unequal channel spacing, larger spacings

- Self/Cross Phase Modulation (SPM, XPM)

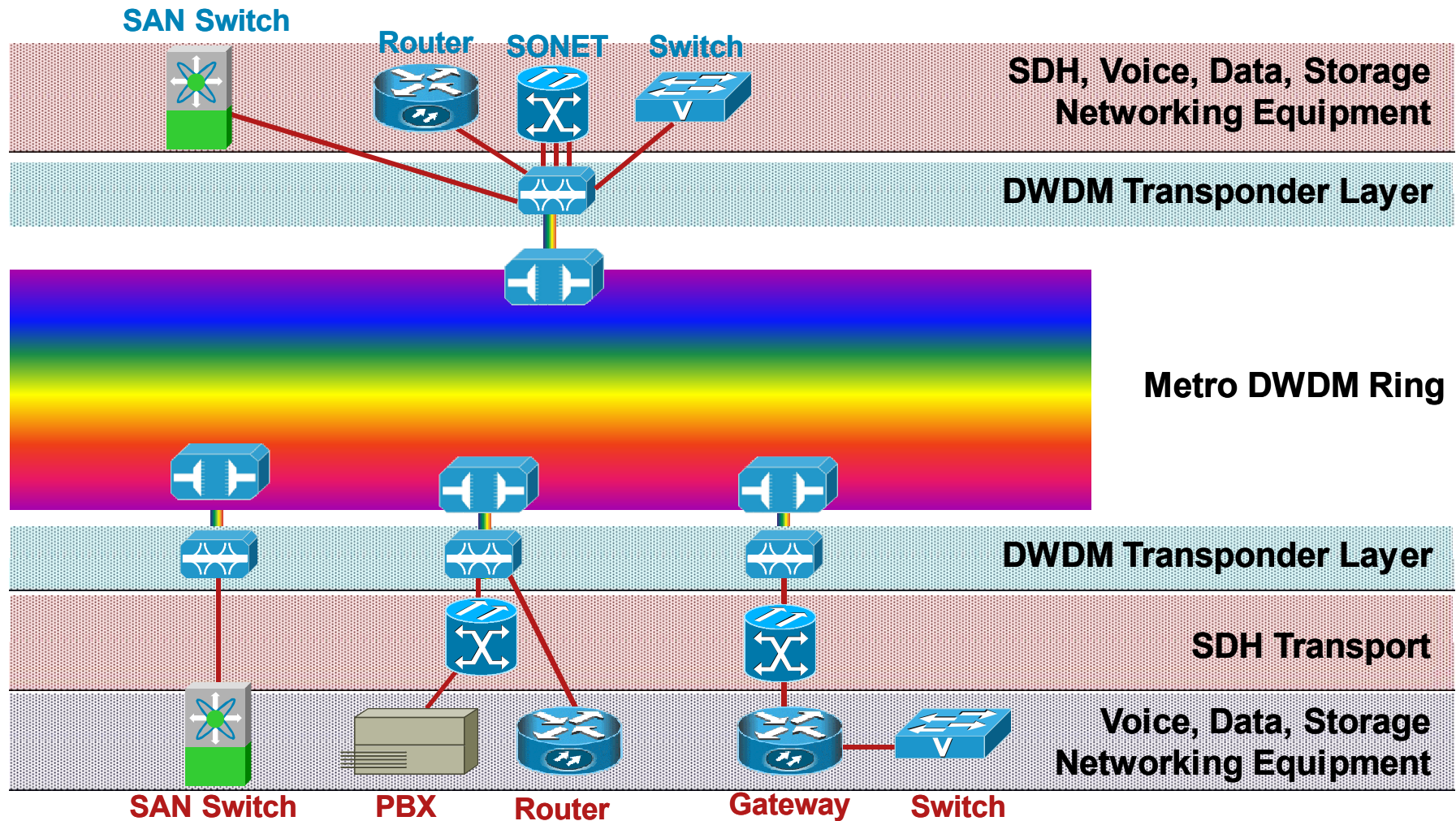
Effected by high channel power

Effected by neighbor channels

CD, reduce launch power, larger spacings



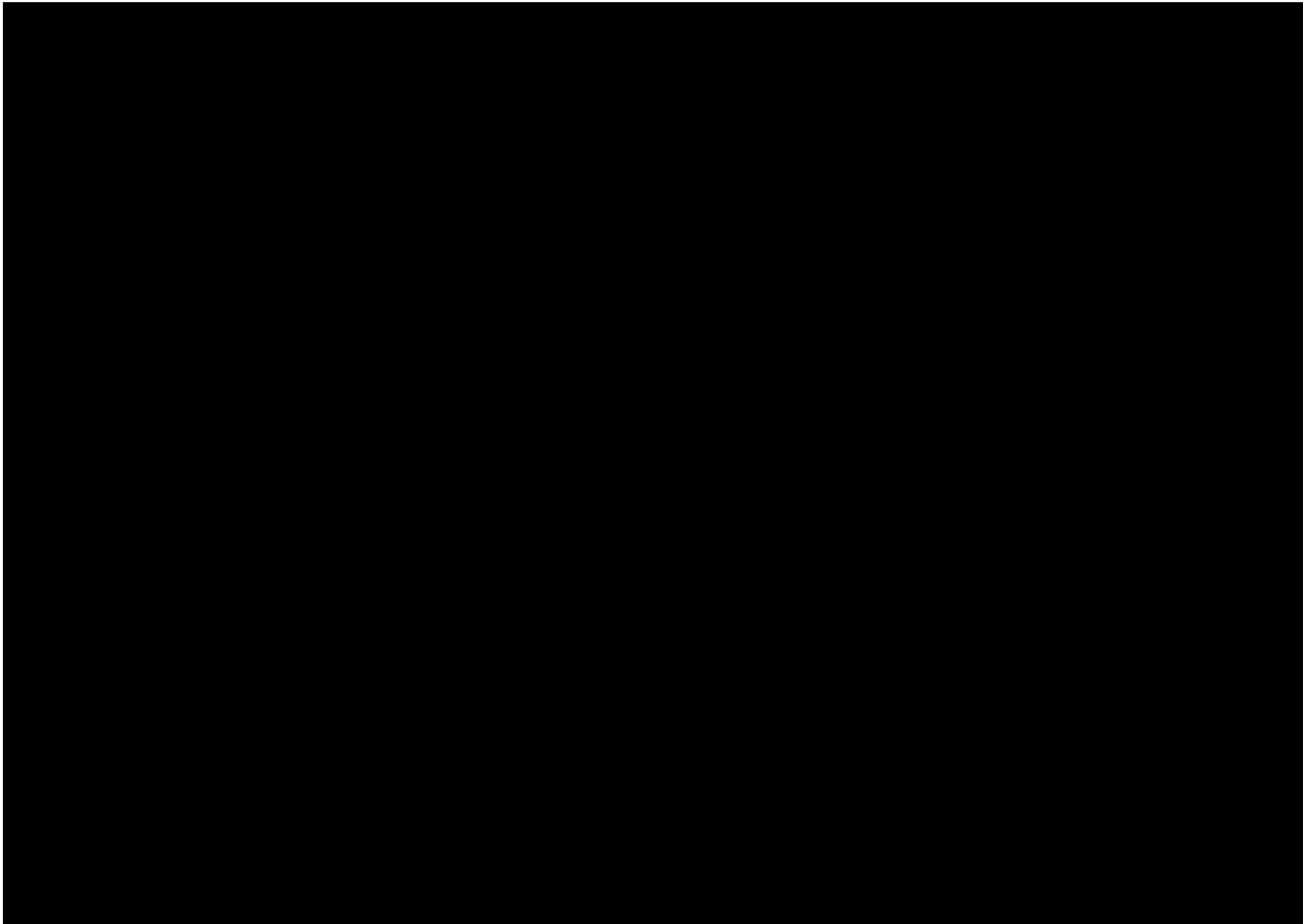
Fundamental Components of a DWDM Network



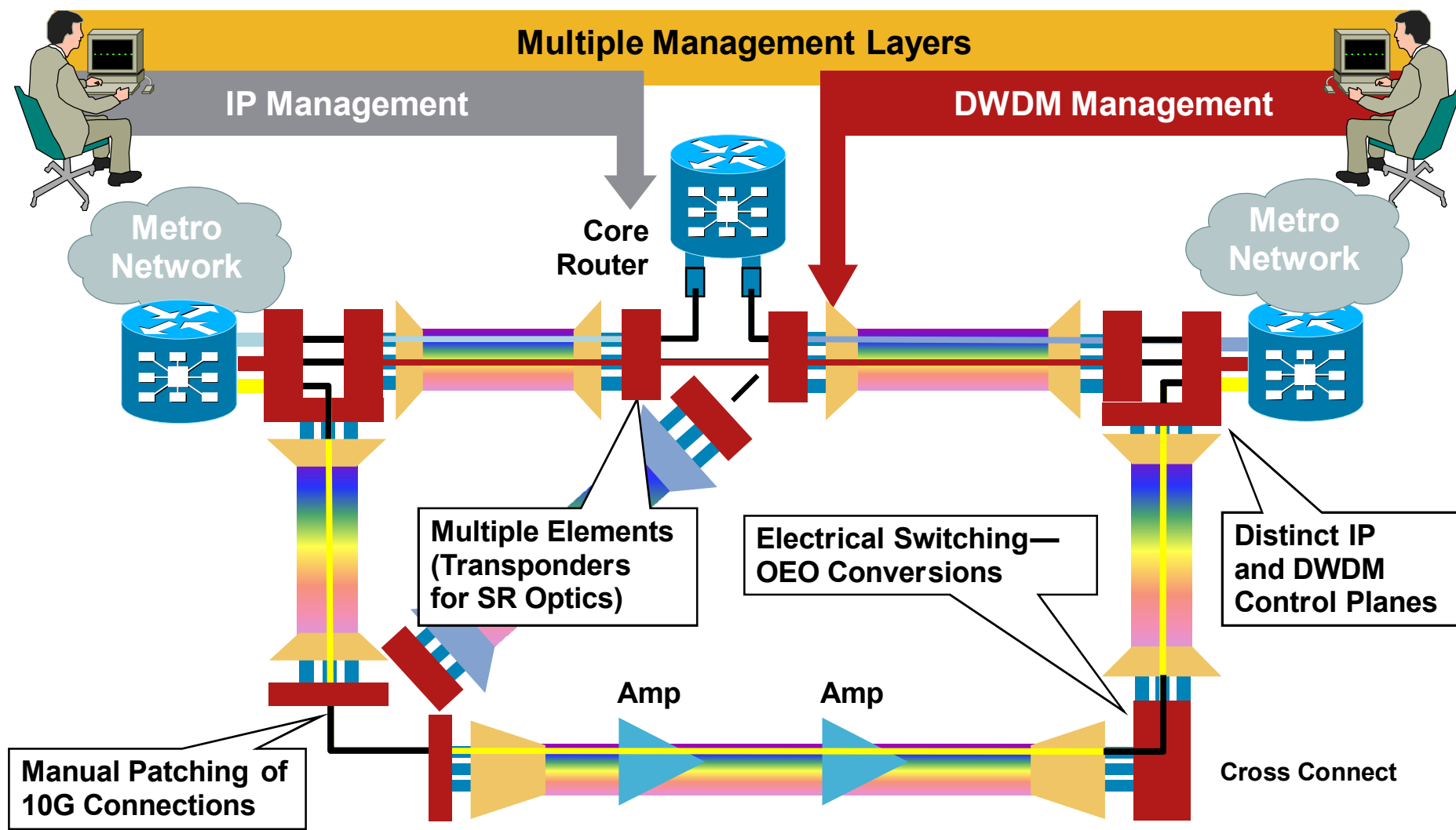


IPoDWDM Network Architecture





Challenges for IP and DWDM Networks

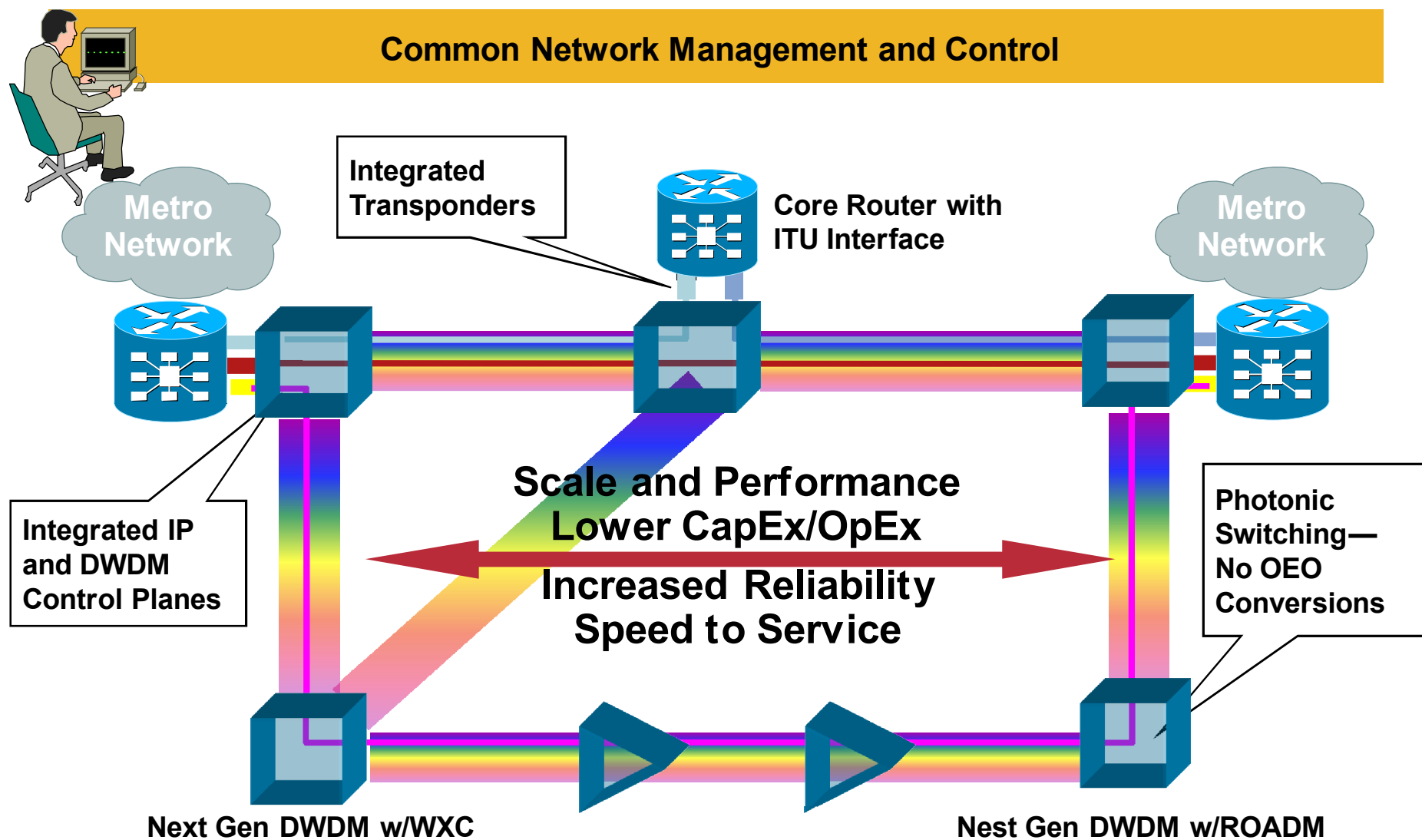


Evolution of Core Transport Networks

- Transport networks today are based on SONET/SDH because it offers:
 1. Operational efficiency (OAM&P)
 2. Fast protection (< 50 ms, as originally designed for voice circuits)
 3. Efficient grooming at the sub-wavelength level
- Efficient grooming at the sub-wavelength level is no longer valid:

Due to traffic growth, it is now cost-effective to carry router-to-router traffic over a dedicated wavelength
- If other network layers could take on SONET/SDH functions, the network of the future could be much simpler

New NGN IPoDWDM Architecture



Substituting Key SONET/SDH Functions in NG IPoDWDM Network Architecture

- Easy operations (OAM&P)

 - G.709 overheads mimic SONET/SDH functions

 - GMPLS allows optical layer visibility into hard to detect failures

 - Integrated optics → low-cost optical monitoring and provisioning

- Fast protection

 - Integrated DWDM interfaces of a router enable fast triggers

 - Router-based fast reroute (FRR) may be more economical and as fast and reliable as SONET/SDH ring-based protection

- Sub-wavelength grooming

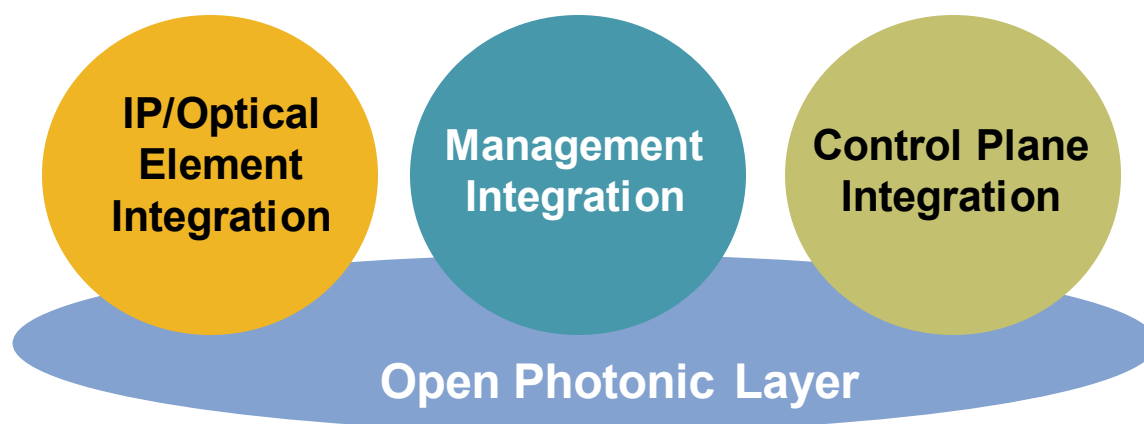
 - Not needed- router trunks can fill 10G/40G wavelengths

 - Manage bandwidth at the wavelength level using optical switches

Conclusion: SONET/SDH Functions Are Replaced by MPLS + G.709 + DWDM, Allowing for a Simpler, More Scalable Architecture

IPoDWDM

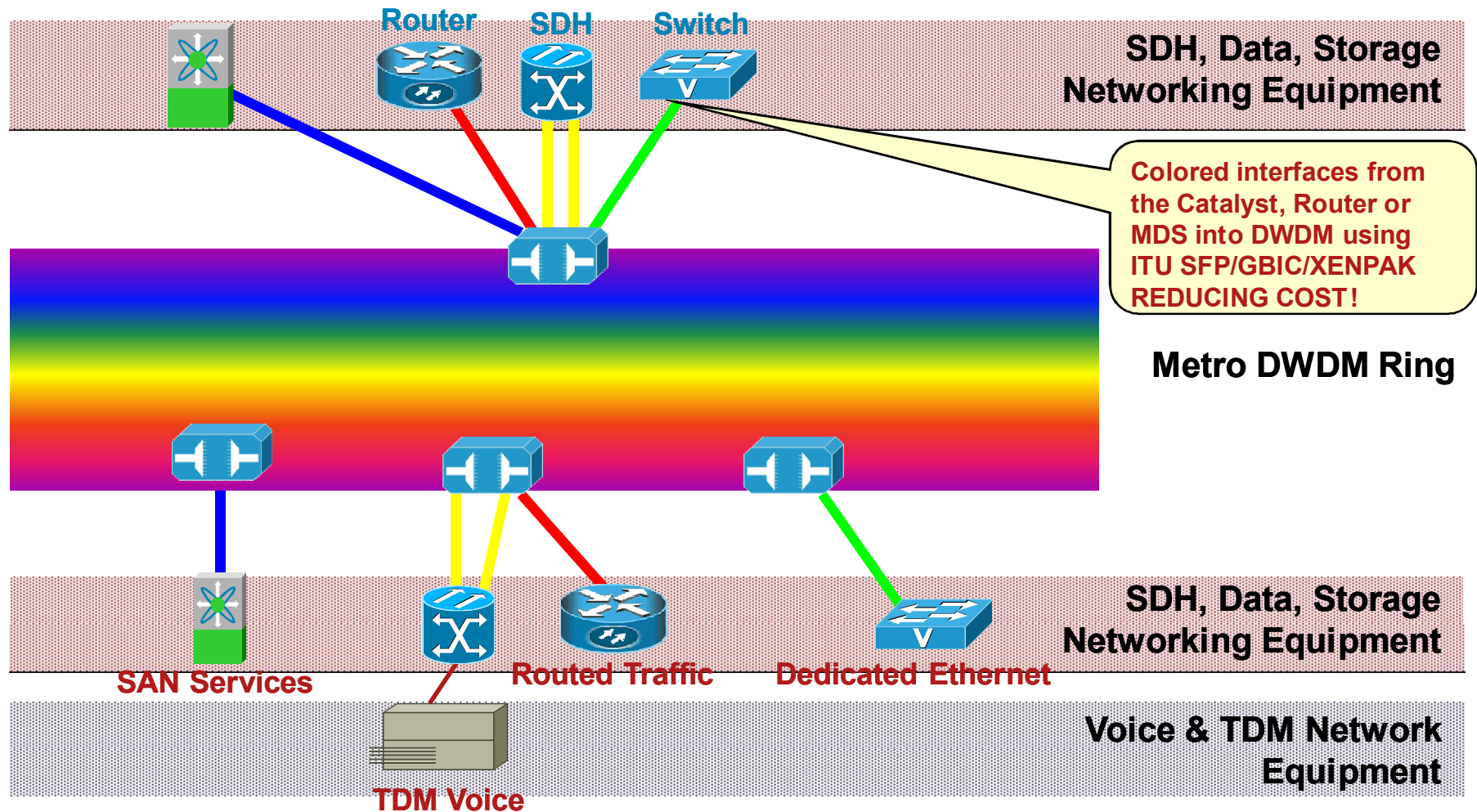
Building Blocks and Technologies



- 10G DWDM interface on routers/switches as an entry point into the optical domain
- 40G DWDM interface over 10gbps optimized transmission
- 2.5G WDM SFP/GBIC for lower end applications
- Advanced DWDM layer w/ extensive optical control loops and monitoring

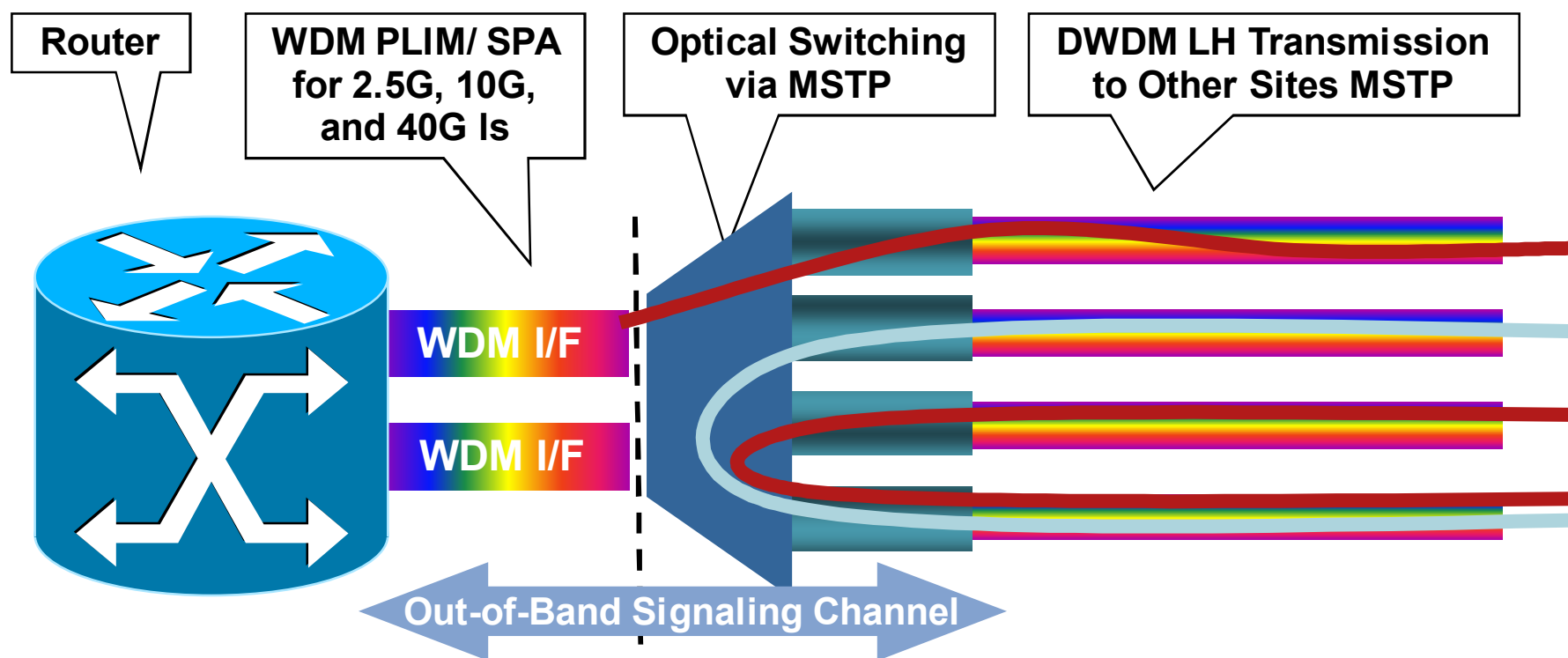
- Ring optical switching using ROADMs
- Mesh optical switching using routers/WXC
- Control plan technologies:
 - LMP
 - Peer model (GMPLS)
 - Overlay model (O-UNI)
- Network management integration

Cisco's Pluggable IPoDWDM Implemented



Base Architecture

Integrated EMS (Router + Transport)



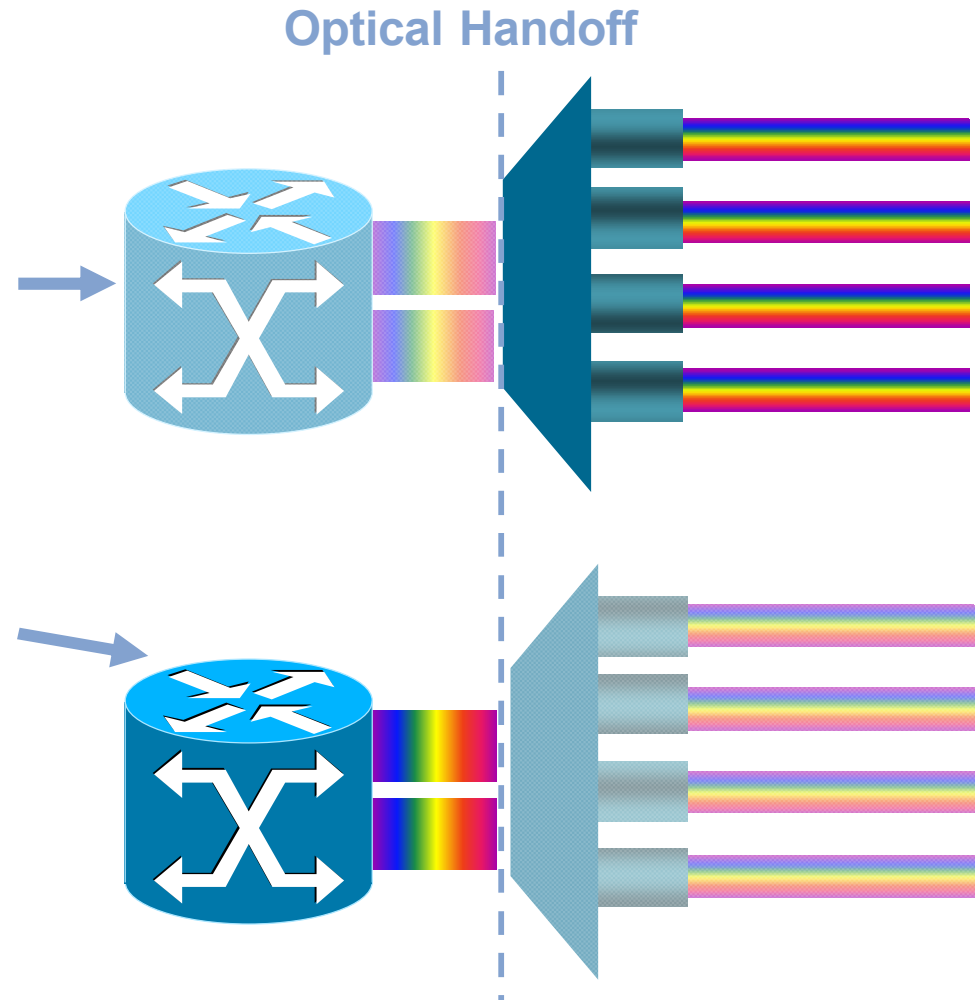
Innovative Extensions to GMPLS to Make It DWDM Aware

IPoDWDM Uses an “Open” ITU-Compliant Interface

- Any client can connect to MSTP via transponders or with ITU-compliant colored interfaces

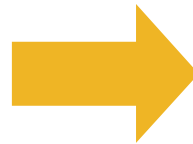
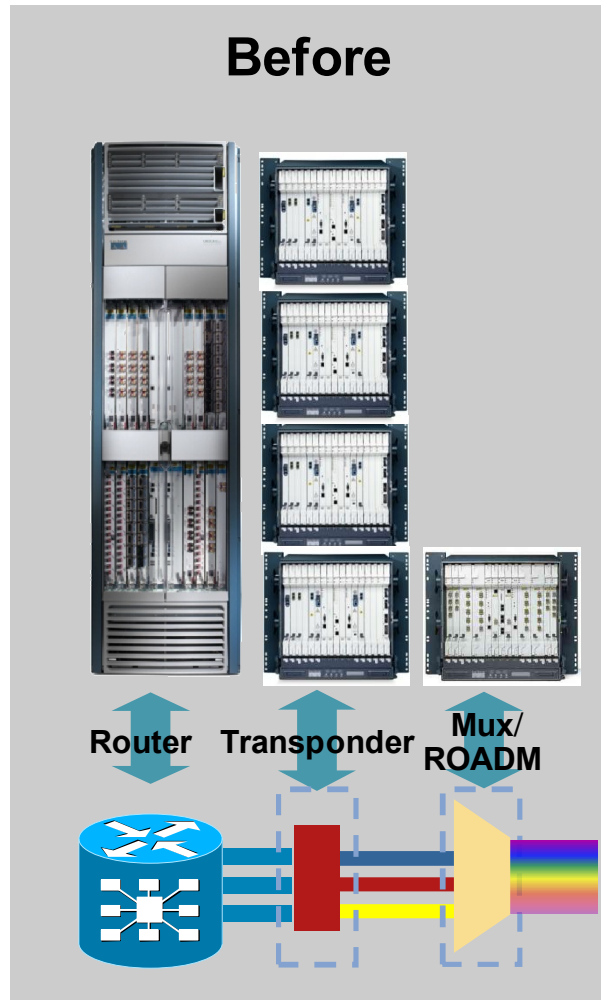
Any alien wavelength+

- Colored router interfaces can directly connect into any ITU compliant third-party DWDM layer
- The optical handoff standard will be driven via the Open Transport Initiative (OTI) hosted by Comcast



Benefits of IPoDWDM

CapEx, OpEx Performance



Cisco Innovation

Industry Leading IPoDWDM on CRS-1

■ Element Integration

Tunable 1 port 40G (OC-768/STM-256) WDMPOS;
compatible with 10G DWDM systems

Tunable 4 port 10GE WDMPHY; SONET/SDH-like OAM&P
at 10GE price points

Enhanced FEC - up to 1000km distance (500% increase)

Fully interoperable with 15454

Designed to interoperate with 3rd party DWDM

■ Control Integration

Segmentation model for GMPLS (S-GMPLS)

■ Management Integration

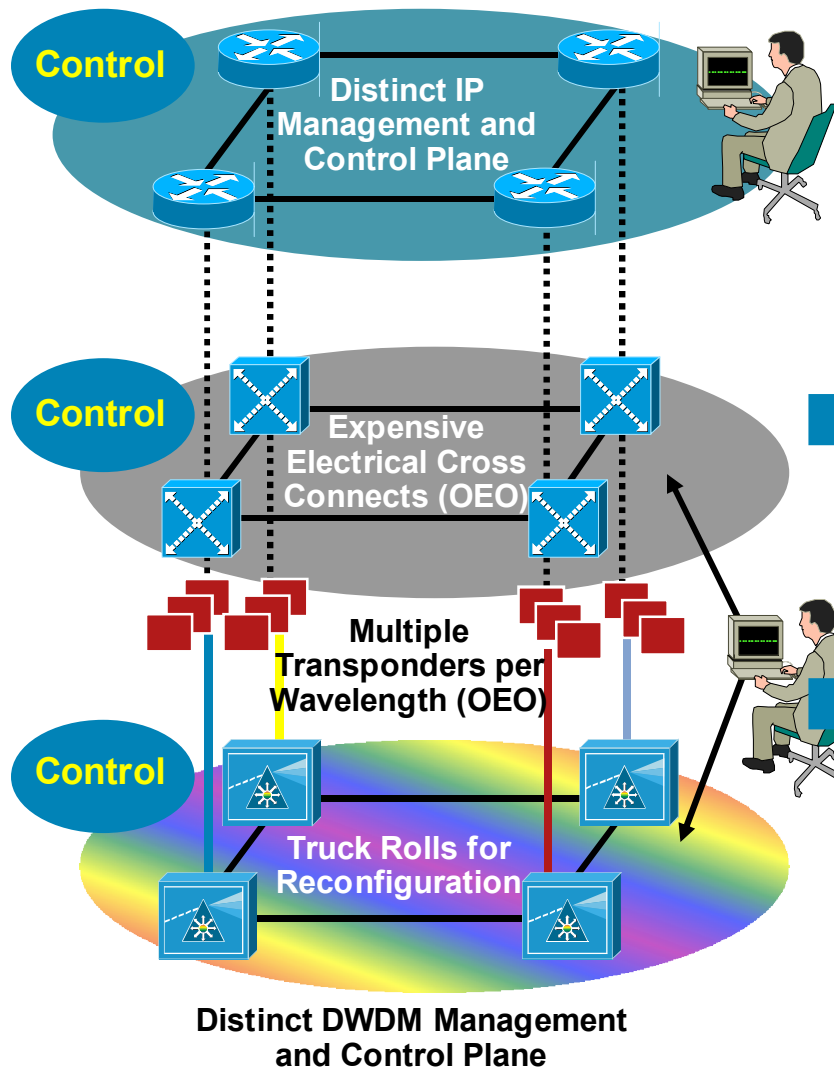
Cisco IP over DWDM design tools

SONET/SDH-like OAMP for perf monitoring

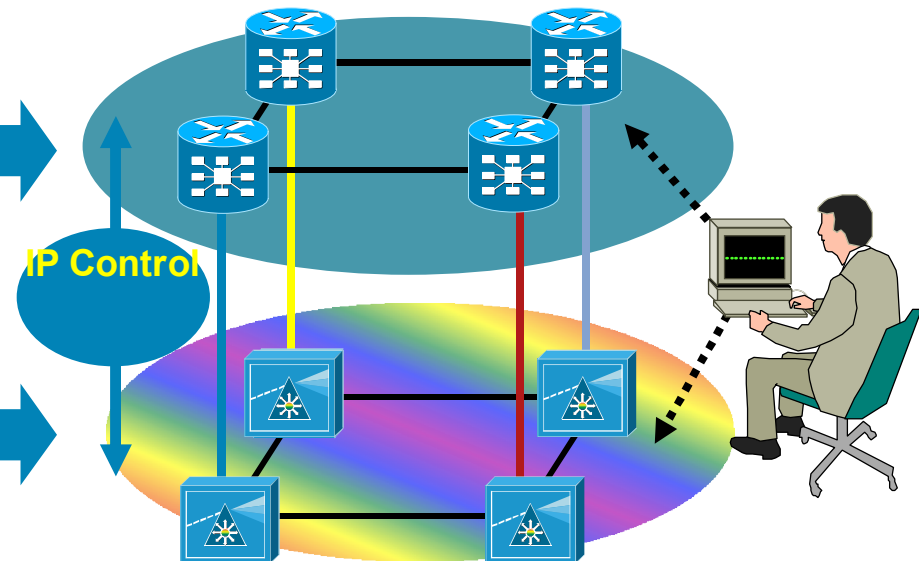
Open architecture for 3rd party interoperability



How Does IPoDWDM Simplify the Network



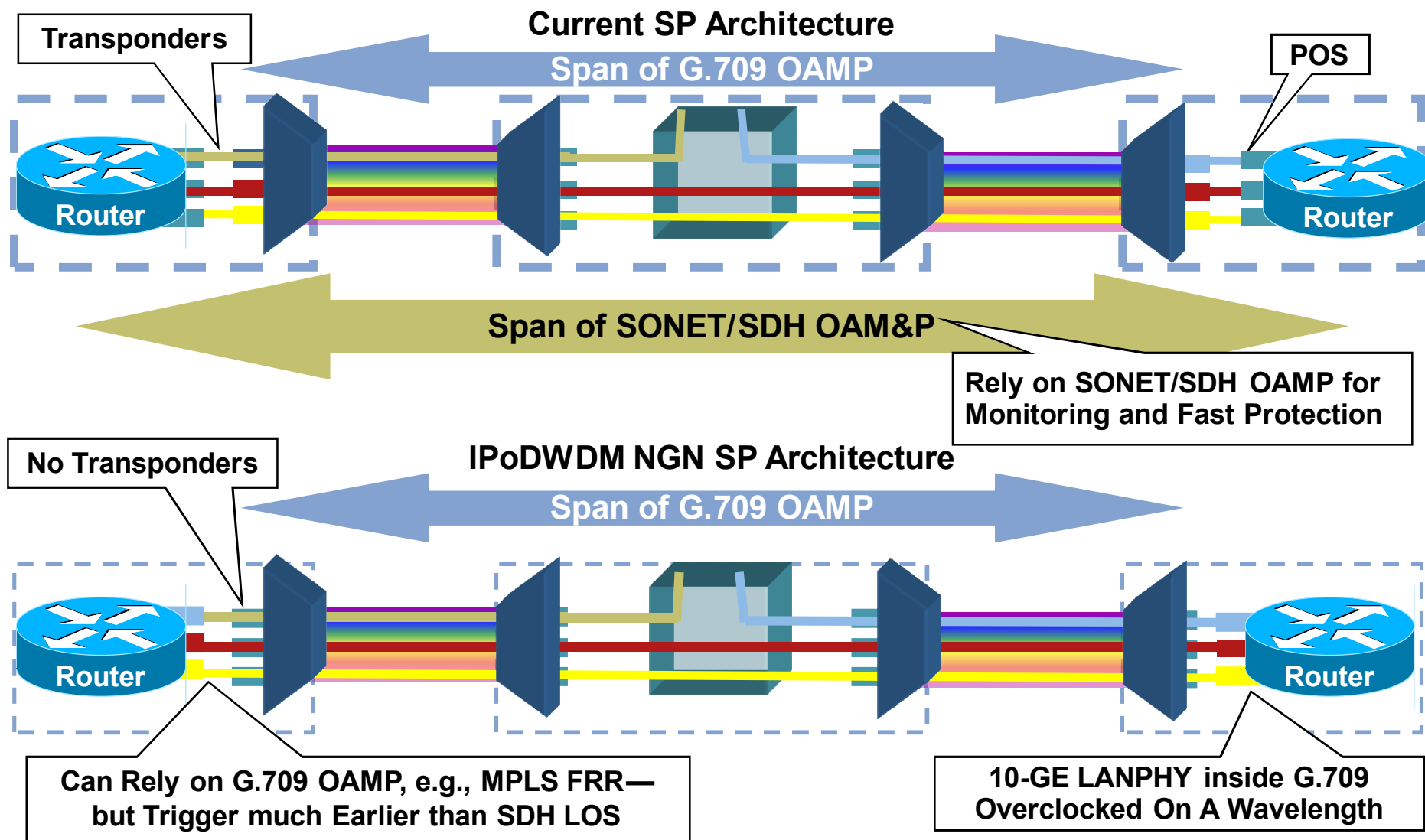
- Single intelligent IP control plane for delivering service flexibility and lower OpEx
- Segmented or integrated management model for faster provisioning, reduced OpEx



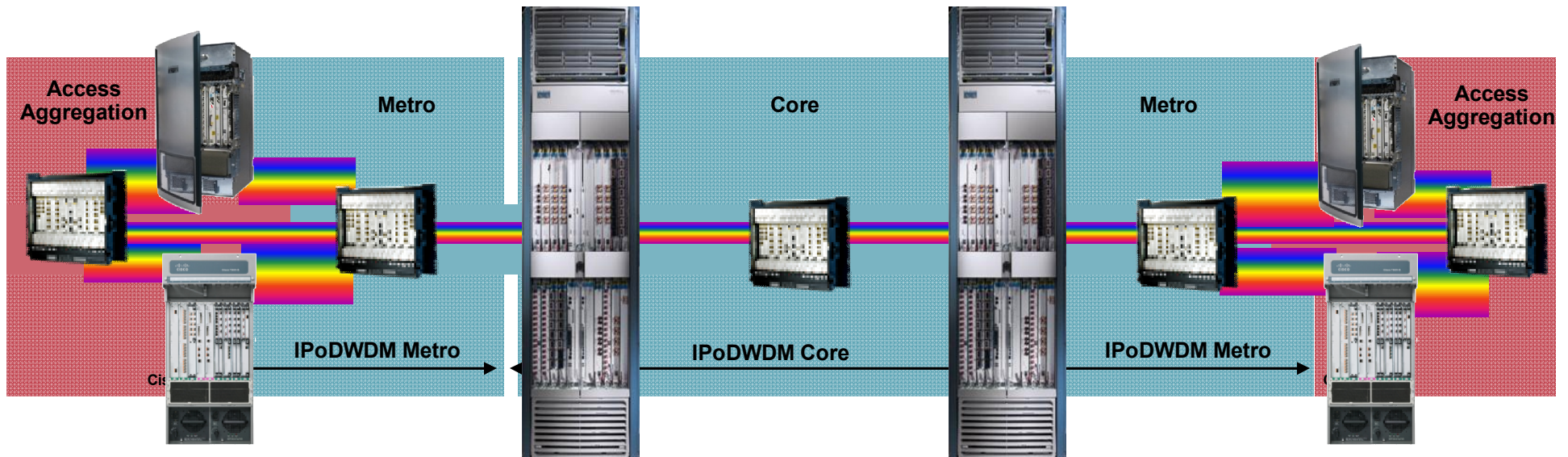
- Integrated transponders lower CapEx/OpEx, increase reliability
- ROADMs eliminate OEO and minimize truck rolls for reliability, service flexibility, and lower OpEx

IPoDWDM Architectures with WDMPHY

End-to-End G.709 OAMP



IPoDWDM Framework



12K

- 1 X 10Gig E IPoDWDM SPA

CSR-1

- 4 X 10Gig IPoDWDM interface
- 1 X 40G IPoDWDM interface (ODB)
- 1 X 40G IPoDWDM interface (DPSK+)

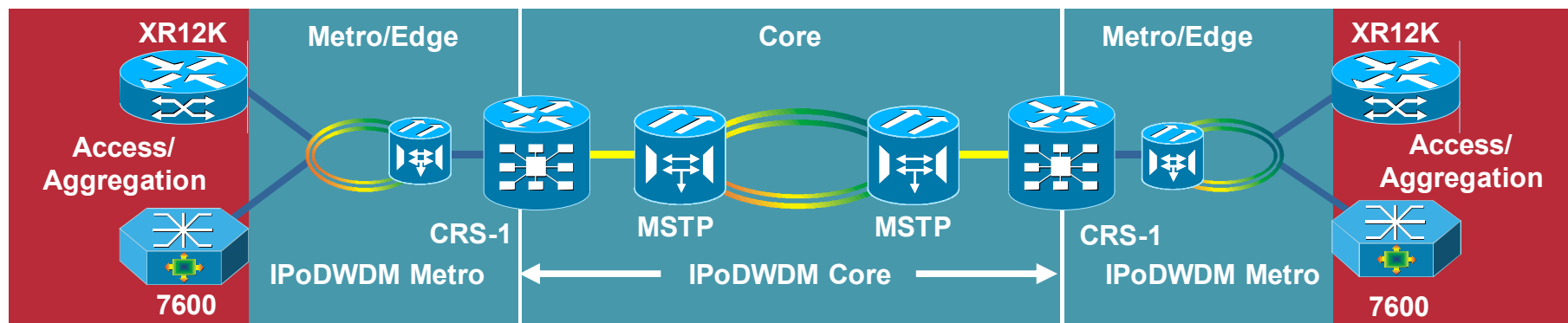
MSTP

- 2 degree ROADM
- Omni Directional Mesh ROADM
- Xponders for Metro / Access IPoDWDM aggregation

7600

- 4 X 10Gig XFP IPoDWDM interface (2H08)

IPoDWDM—Not Just for the Core



Feature	IPoDWDM Core	IPoDWDM Metro
Network Location	Core	Metro/Access
Packet Platform	Core Routers	Routers and Switches
OAM&P Reqs	High (G.709)	Lower (Native Packet)
Optical Technology	High-End DWDM	Pluggable (XFP, XENPAK)
Protection	FRR, IP	Native (Eth, IP, FRR, RPR)
Distances	Long (1000 km +)	Short (100. 200 km)
Tunability	Important	Desired
Why Stay Photonic?	Bandwidth Scaling	Service Diversity

